The effect of an erbium, chromium: yttrium-scandium-gallium-garnet laser on the microleakage and bond strength of silorane and micro-hybrid composite restorations

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ABSTRACT

Objective: The aim of this *in vitro* study was to compare the microleakage and bond strength of Class V silorane-based and universal micro-hybrid composite restorations prepared either with diamond bur or with an erbium, chromium: yttrium-scandium-gallium-garnet (Er, Cr:YSGG) laser. **Materials and Methods:** A total of 160 molar teeth were used for microleakage assessment and shear bond strength (SBS) test. The specimens were prepared using either diamond bur or 3 W-, 4 W- and 5 W-20 Hz Er, Cr:YSGG laser irradiation. All specimens were subjected to thermocycling (500 times at 5 ± 2°C to 55 ± 2°C, dwell time 15 s and transfer time 10 s). Microleakage was assessed using a 0.5% basic-fuchsin solution. The bond strengths were determined using a microtensile tester at a crosshead speed of 0.5 mm/min. The Kruskal Wallis test was used for the analysis of microleakage and a one-way analysis of variance test was used to analyze the SBS ($P < 0.05$). **Results:** No statistically significant differences were found ($P > 0.05$) between Er, Cr:YSGG laser and bur preparation methods regarding microleakage and bond strength values. **Conclusion:** Irradiation with Er, Cr:YSGG laser was confirmed to be as effective as conventional methods for preparing cavities before adhesive restorations.

Key words: Diamond bur, erbium, chromium: yttrium-scandium-gallium-garnet laser, micro-hybrid composite, silorane

INTRODUCTION

Restorative composite resins have undergone continuous development during recent decades. Although the current composites exhibit excellent physical resistance and esthetic properties, there are still several problems related to shrinkage during polymerization and bacterial invasion.[1] Siloranes are popular restorative materials that have been synthesized to overcome the problems related to the polymerization shrinkage.[2-5] The manufacturer recommends this material to reduce the risk of post-operative sensitivity, cusp deflection and enamel cracks.[1,2,5]

In the field of dentistry, there has been growing interest in the use of lasers for various applications, including cavity preparation, due to their ability to efficiently remove dentin and enamel.[6-8] The erbium, chromium: yttrium-scandium-gallium-garnet (Er, Cr:YSGG) laser has been used in a clinical setting to prepare cavities; it provides the same clinical effectiveness compared with bur, but reduces pain and discomfort by eliminating pressure and intense vibration. Furthermore, the Er, Cr:YSGG laser provides a more conservative method for cavity preparation that is associated with minimal injury to the pulp, less noise and in most cases, a significantly reduced need for local anesthesia.[7,9-11]

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Microleakage at the tooth-adhesive interface is another important factor to be considered with respect to the long-term durability of the bonding.[12] When considering a laser for routine use, it is essential that the laser does not adversely influence the marginal integrity of the resulting restoration.[13,14] The Er, Cr:YSGG laser uses a pulsed irradiation mode and the energy is delivered through a proprietary flexible fiber to a handpiece, which is attached to a sapphire tip with a diameter of 0.4 or 0.6 mm. During irradiation and between pulses, the tissues are bathed in a water mist spray and this spray is employed for most soft-tissue surgical procedures and when cutting enamel and dentine.[7,14,15]

Laser-induced changes in the surface texture of enamel and dentine could potentially affect the microleakage and bond strength of adhesive restorative materials.[12,14] The characteristics of the enamel and dentine after irradiation with the Er, Cr:YSGG laser have been reported to produce an anfractuous surface (fractured and uneven) suitable for adhesion, with open tubules, the absence of a smear layer, a scaly appearance or an irregular surface and no thermal injury.[16] The application of the laser to the dentin surface is thought to provide an advantage because of the apparently enlarged surface area available for adhesion following laser irradiation. While some authors[9,11] believe that the laser may be able to provide restorations that have better microleakage results, greater bond strength and greater longevity than those obtained by the conventional method, others[17,18] have reported that the laser did not improve adhesive procedures and that it actually hampered them.[16] Ceballos *et al*.[10] proposed that the ablation of dentin resulted in fusion of the collagen fibrills, resulting in a lack of interfibrillar space and restricting the diffusion of resin into the subsurface intertubular dentin, which is the most likely explanation for lower bond strengths. Shigetani *et al*.[19] compared the marginal seal of enamel and dentin between cavities prepared by erbium: yttrium-aluminum-garnet (Er:YAG) laser irridiation and drilling and found no significant differences.

The effectiveness of lasers and their impact on the adjacent tissues depend on parameter settings, such as the irradiation time, the pulse energy, the pulse repetition rate, the pulse duration, the emission mode, the efficiency of tissue cooling using water, the rates of water and air flow and the distance between the laser device and the tooth surface.[6,7,9,14,15,20,21] Several authors have used different power settings for the lasers when comparing the micro-shear bond strength (SBS) of composite restorations to tooth surfaces prepared using the Er, Cr:YSGG laser or a conventional method.[8,9,22]

The marginal integrity and the bond strength are the major important factors in the success of restorations.[3,4,11,23] Currently, none of the available materials and technics are able to prevent microleakage for Class V cavities.[24-26] Data on the quality of the margins of composite fillings in relation to the use of an Er, Cr:YSGG laser for hard tissue preparation have been described.[7,14,15,20,21,27,28] Previous studies[1,4,5] have shown a significantly improved marginal integrity of silorane-based composite (SBC) compared with methacrylate-based composites (MBCs) on both enamel and dentin in cavities prepared with a water-cooled high-speed diamond bur. It can be expexted that the differences in surface alterations following the use of laser and conventional bur preparation techniques would influence microleakage and bond strength depending on the composite and adhesive system used.[11] The microleakage and bond strengths of the tooth substrate on Er, Cr:YSGG lased tooth surfaces that have been reported in the literature are often confusing and even contradictory.[6-8,11,12,14,15,21,22] Therefore, the purpose of this *in vitro* study was to compare the microleakage and bond strength of Class V silorane-based micro-hybrid composite (Filtek Silorane) and universal micro-hybrid composite (Filtek Z250) restorations prepared either with a conventional diamond bur or with an Er, Cr:YSGG laser at different power levels.

MATERIALS AND METHODS

Tooth selection

A total of 160 intact human third molar teeth that were free of caries and had no other microscopic defects and were designated for extraction were extracted. The teeth were stored in distilled water at 4°C for a maximum of 1 month. To prevent bacterial growth, the water was changed weekly. After surface debridement with hand-scaling instruments and cleaning with a slow-speed hand piece and a brush with pumice, 80 specimens were selected for microleakage assessment and 80 were selected for SBS.

Silorane-based composite

Surface preparation

A total of 80 teeth were sectioned 2 mm below the cemento-enamel junction with a slow-speed diamond saw sectioning machine (Isomet; Buchler Ltd., Lake

Bluff, Illinois, USA) and the crowns were embadded in autopolymerizing acrylic resin (Meliodent; Bayer Dental Ltd., Newbury, UK) with the labial surface facing up for surface treatment and composite bonding. After polymerization of the embadding resin, the buccal surfaces were ground with water-cooled silicon carbide of grit size 400-600 and then sequentially polished in a polishing machine (Mecapol P230, Presi Tavernoles 38 and Brieet Angonnes, France) to produce a uniform smear layer. After it had been confirmed with a stereo-microscope that no dentin was exposed on the enamel surfaces (Nikon SE, Tokyo, Japan), the specimens were divided into four groups. In Group 1, the enamel surfaces were prepared with a water-cooled high-speed hand piece (Kavo Supertorque 630B, Kavo Co., Biberach, Germany) and a diamond bur (Komet ISO 806 314 110524012 (836), Brasseler Gmbh Co., Lemgo, Germany). A surface area of approximately 4 mm × 4 mm was prepared in this manner. In Groups 2, 3 and 4, the enamel surfaces were irradiated with an Er, Cr:YSGG laser (Waterlase MD, Biolase Technology Inc., San Clemente, CA, USA) under 95% air flow and 85% water flow using a contact tip with a repetition rate of 20 Hz (20 pulses/s) and the output power was set to 3 W (150 mJ/Pulse), 4 W (200 mJ/Pulse) or 5 W (250 mJ/Pulse), respectively. The Er, Cr:YSGG laser system was operated at a wavelength of 2,790 nm with pulse duration of 140-200 μs. The laser energy was delivered through a fiberoptic system to a sapphire tip terminal that was 600 μm in diameter and 6 mm long with a tip-to-target distance of 1 mm. To standardize the distances and to control the size of the irradiation area, an acrylic disc of thickness 1 mm was prepared. A 4 mm × 4 mm hole was prepared on the surface of the acrylic disc. This acrylic resin with a 4 mm × 4 mm hole helps to avoid unnecessary laser irradiation.[9] In each group, half of the samples (n = 10) were restored with Filtek Silorane (3M ESPE, St. Paul, MN, USA, Lot no. 7AX) with the silorane adhesive system (3M ESPE, Seefeld, Germany, Lot no. 7AE) while the others were restored with Filtek Z250 (3M, ESPE, St. Paul, MN, USA, Lot no. 6020A2) with Adper Single Bond Plus (3M ESPE, St. Paul, MN, USA) according to the manufacturer's instructions [Table 1].

Following the respective pretreatment sequences, a teflon tube with an inner diameter of 3 mm and a height of 2 mm was attached to the prepared enamel surfaces. The micro-hybrid composite resin was inserted into the teflon tube incremantally, each polymerized for 40 s (Curing light XL 3000™, 3M Dental Products, St. Paul, MN, USA). After curing had been completed, the teflon tube surrounding the composite was carefully removed.

SBS testing

The samples were stored in distilled water at 37°C for 24 h and then subjected to thermocycling for a total of 500 cycles at 5-55°C with a dwell time of 30 s. The specimens were then tested in shear mode by using a shear knife-edge blade in a universal testing machine (Instron Corporation, Canton, MA, USA) with a crosshead speed of 0.5 mm/s. The maximum load to failure was recorded for each sample and the SBS was expressed in megapascals, which is derived by dividing the imposed force Newtons (N) by the bond area (mm^2).

Microleakage

Cavity preparation and restoration

Class V cavities were prepared on both the buccal and lingual surfaces of each tooth, with the occlusal margins in the enamel and the cervical margins located 2 mm apical to the cemento-enamel junction. The cavity dimensions were standardized with a template that was 3 mm wide and 3 mm high. The depth of the cavity was 3 mm and was measured and controlled by a pre-marked periodontal probe.

The 80 teeth selected for microleakage were divided into four subgruops (n = 20). In the first group, Class V

Table 1: Summary of the dentin bonding systems and composite resins used for restoration

Material	Manufacturer	Lot no.	Composition
Filtek Silorane	3M ESPE, St. Paul, MN, USA	7AX	Silanized quartz; yttrium fluoride, 76 wt%; 3,4-epoxycylohexyl-ethylcylophenyl-methylsilane
Filtek Z250	3M, ESPE St. Paul, MN, USA	6020A2	BIS-GMA, BIS-EMA, UDMA, zirconia/silica (82% w/w, 60% v/v)
Silorane adhesive system	3M ESPE, Seefeld, Germany	7AE	Phosphorylated methacrylates; Vitrebond™ copolymer silane-treated silica filler; phosphorylated methacrylates
Adper Single Bond Plus	3M ESPE, St. Paul, MN, USA	51102	Bis-GMA, HEMA, dimethacrylates, ethanol, water, nanofiller, a novel photo-initiator system, a methacrylate functional copolymer of polyacrylic and polyitaconic acids

BIS-GMA: Bisphenol A glycol dimethacrylate, BIS-EMA: Bisphenol A polyethylene glycol diether dimethacrylate, UDMA: Urethane dimethacrylate, HEMA: 2-hydroxyethylmethacrylate

cavities (3 mm × 3 mm × 3 mm) prepared on the buccal and lingual surfaces of the teeth using a water-cooled high-speed hand piece and a diamond bur, which was changed after every four preparations.

Class V cavities were prepared similarly in the other three groups using Er, Cr:YSGG laser irradiation. The output power parameters for Group 2, 3 and 4 specimens were 3 W (150 mJ/Pulse), 4 W (200 mJ/Pulse) and 5 W (250 mJ/Pulse) with a repetition rate of 20 Hz, respectively. For enamel and dentine cutting, the manufacturer's recommended settings were used; namely, for enamel a power of 3 W, 4 W or 5 W was used with 95% air flow and 85% water flow and for dentine, a power of 2 W (100 mJ/Pulse), 2.5 W (125 mJ/Pulse) or 3 W was used with 75% air flow and 65% water flow.

In this study, two different composite resins were used to restore the teeth: the Filtek Silorone and its dedicated adhesive or the silorane adhesive system with a micro-hybrid composite Filtek Z250 and a total-etch adhesive, Adper Single Bond Plus. Each bonding system was used according to the manufacturer's instructions. The composite resins were applied in three increments, against the gingival wall, against the occlusal wall and flush with the contour of the tooth and then covered with a transparent matrix strip (Ruwa Matrix Strips, Demetron Research Co., Danbury, CT, USA). Each increment was lightcured for 40 s. Finishing was carried out immediately after polymerization using graded Soflex discs (3M Dental Products, St. Paul, MN, USA) according to the manufacturer's instructions.

Assessment of microleakage

The specimens were subjected to a thermocycling regimen; all teeth were then placed in deionized water at 37°C for 24 h and thermocycled (500 times at 5 ± 2°C to 55 ± 2°C; dwell time 15 s and transfer time 10 s). Marginal leakage was evaluated by a conventional dye-penetration method. The apices of the teeth were sealed with epoxy resin (Struers, Copenhagen, Denmark) and the specimens were covered with two coats of nail varnish up to 1 mm from the sealant margins to prevent dye infiltration. The specimens were then immersed in 0.5% basic-fuchsin solution (Wako Pure Chemical Industry; Osaka, Japan) for 24 h at 37°C.

After being rinsed with distilled water, each specimen was embedded in epoxy resin and subsequently sectioned longitudinally in a bucco-lingual plane through the midpoint of the restorations with a water-cooled, slow-speed diamond saw (Mecatome T201, Presi, France) to provide two sections of each tooth. The cut sections were examined under a stereo-microscope (Olympus SZ 40, SZ-PT, Tokyo, Japan) at ×20 magnification by two examiners who were unaware of the groupings of the teeth and the teeth were scored using the linear scoring criteria shown in Table 2. Both sections of each tooth were examined and the worst scores for both the occlusal (enamel) and gingival (dentine) margins were used for the data analysis.

Statistical analysis

The results were recorded and analyzed using the statistical package Statistical Package for the Social Sciences (SPSS) 14.0.0 for Windows (SPSS Inc., Chicago, IL, USA). The inter-examiner reproducibility was analyzed with the kappa statistic for microleakage scores. The Kruskal Wallis test was used for comparing the microleakage scores among the groups and composites in the occlusal and the gingival margins and the SBS data were analyzed using one-way analysis of variance tests at a confidence interval of 95%.

RESULTS

The inter-examiner agreement had a kappa value of 0.88 for the sections. The distributions of marginal leakage scores according to the groups are presented in Table 3 and descriptive statistics, including the median (min-max) and the statistical differences are shown in Table 4. The mean values and standard deviations of the SBS for each experimental group are shown in Table 5.

Table 2: Criteria for microleakage scoring

Score	Definition
0	No dye penetration
1	Dye penetration up to one third of the cavity depth
2	Dye penetration up to two thirds of the cavity depth
3	Dye penetration up to three thirds of the cavity depth
4	Extensive dye penetration to and into the pulpal floor/ axial wall

Table 3: Microleakage scores of all cavities

Groups	Margin	Silorane					Filtek Z250				
		0	1	2	3	4	0	1	2	3	4
1	Occlusal	16	2	1	1	0	15	3	0	1	1
	Gingival	15	2	2	1	0	14	3	1	1	1
2	Occlusal	17	2	0	1	0	15	3	1	1	0
	Gingival	17	1	1	1	0	14	4	1	1	0
3	Occlusal	18	1	1	0	0	16	2	2	0	0
	Gingival	17	2	1	0	0	16	3	1	0	0
4	Occlusal	17	1	1	1	0	17	2	1	0	0
	Gingival	18	2	0	0	0	17	1	1	1	0

Table 4: Descriptive statistics for marginal microleakage

Group	Occlusal (Silorane) Median (min-max)	Gingival (Silorane) Median (min-max)	Occlusal (Filtek Z250) Median (min-max)	Gingival (Filtek Z250) Median (min-max)
1	0 (0-3)	0 (0-3)	0 (0-4)	0 (0-4)
2	0 (0-3)	0 (0-3)	0 (0-3)	0 (0-3)
3	0 (0-2)	0 (0-2)	0 (0-2)	0 (0-2)
4	0 (0-1)	0 (0-1)	0 (0-2)	0 (0-3)

P>0.05 for all groups

Table 5: Shear bond strengths (mean ± SD, MPa) of the tested materials in all groups

Group	Silorane (*n*=10) (mean±SD, MPa)	Filtek Z250 (*n*=10) (mean±SD, MPa)
1	15.42±3.82	14.22±2.12
2	13.43±2.37	12.03±2.13
3	12.33±1.16	11.23±1.06
4	14.52±0.62	13.24±1.72

P>0.05 for all groups, SD: Standard deviation, MPa: Megapascals

No statistically significant differences were found ($P > 0.05$) between the methods of preparation (groups) and the composites regarding microleakages in either the occlusal or the gingival margins or in the bond strength values for diamond bur and the Er, Cr:YSGG laser at different power levels. Although no significant differences were found between the composites, silorane exhibited slight microleakages and higher SBS values compared with Filtek Z250 ($P > 0.05$).

DISCUSSION

This study was conducted to compare the SBS and microleakage of silorane and micro-hybrid composite restorations prepared with a conventional diamond bur or Er, Cr:YSGG laser using different power levels. The results of the present study showed that composite restorations prepared with diamond bur and laser at different power levels may result in similar bond strength and microleakage, Silorane exhibited similar microleakage and SBS values compared with micro-hybrid composite.

Several studies[20,23-29] investigated the bond strengths of different composite resins to pretreated teeth. It was reported that acid etching produces a hybrid layer and the characteristic funnel-shaped resin tags, regardless of the type of surface preparation (bur/laser).[24] In their study, Monghini *et al*.[26] assessed the influence of Er: YAG laser irradiation on the SBS between a total etch adhesive system and lased primary dentin. They found that dentin acid etching is beneficial for adhesion. Bertrand *et al*.[27] showed that the values of the SBS of bur-prepared dentin surfaces that were treated either with acid, with an Er: YAG laser or with an Er: YAG laser and acid did not differ significantly, whereas Trajtenberg *et al*.[28] reported the highest bond strengths when the tooth surfaces were acid-etched after preparation with either a laser or a bur prior to the application of the bonding agent. Celik *et al*.[30] found that Er: YAG laser irradiation did not adversely affect the SBS of Single Bond 2 or clearfil protect bond to dentin, but it positively affected the bond strength of Clearfil tri-S Bond. In their study, da Silva *et al*.[31] found similar results in all groups. A one-step adhesive was not used in our study, but the results for the other materials were comparable. In our study, the bond strengths of all the laser-treated samples were similarly to those prepared with the bur. Although no significant differences were found between the composites, Silorane (with two-step self-etch silorane adhesive) showed slight microleakage and higher bond strength values when compared with Filtek Z250 (the total-etch system). Lima *et al*.[32] found that despite the lower level of enamel etching associated with the self-etching adhesive primer, the etching pattern was able to produce bond strength values similar to those obtained with the etch-and-rinse adhesive system. In addition, it is well-known that smear layers cannot be occurred after the laser irradiation.[21] In our study, the laser groups were restored either Silorane or Filtek Z250. The similar values were obtained in both tested systems. This may also be explained by the fact that the tested teeth had a similar surface morphology after the laser application. The laser creates rough surfaces free of smear layer, extensive surface fissuring, less homogeneous and regular surface patterns.

In the current study, Filtek Z250 and total-etch application were performed after the laser application. Furthermore, acid etching was also performed after the laser application. In some previous studies,[4,21] laser application was used as a pretreatment alone, without acid etching, but there was not any increase in the bond strengths. This may be the similar to the effect of laser and bur preparation whereby the surface roughness is increased before the total-etch adhesives are applied.

Microleakage is a well-known phenomenon that occurs with time and is often responsible for the post-operative sensitivity, discoloration and recurrence of caries in a restored teeth.[16] Several studies have shown that the microleakage is minimal when the bonding between the restoration and the tooth is adequate.[12,18,27,30,33-36] Several previous studies similar to ours investigated the effects of preparation with an erbium laser and convantional burs on marginal microleakage.[10,14,24,37-40] Some of these studies found that lasers produced equal or better microleakage scores than burs,[38-40] and other studies have reported the opposite.[10,24] Similar to our study, Marotti *et al*.[16] stated that preparing the Class V cavity with either a conventional technique using burs or with an Er, Cr:YSGG laser had the same effectiveness in terms of microleakage. Delme *et al*.[41] investigated the effects of preparation with an Er: YAG laser or a diamond bur on microleakage in human teeth *in vitro*. They reported no statistically significant differences between the groups. The results of our study agree with the findings of these previous studies.[16,41] A potential explanation for these results could be that studies on surface alterations of enamel and dentine after Er, Cr:YSGG laser irradiation demonstrate the micro-irregularities on both tissues and the lack of a smear layer. Such alterations result in both macro- and micro-roughness. Laser-induced changes in the surface texture of the enamel and dentine could potentially affect the microleakage of adhesive restorative materials. On the other hand, Gutknecht *et al*.[6] demonstrated that the bond strength is significantly weaker when tooth surfaces are prepared with the Er, Cr:YSGG laser compared with a diamond bur. Lin *et al*.[42] explained that the Er, Cr:YSGG laser ablates hard tissues thermomechanically by making micro-explosions within the inorganic structures of the teeth. Sennou *et al*.[43] proposed that ablation of dentin fuses collagen fibrils together, resulting in the lack of an interfibrillar space and preventing resin from diffusing into the subsurface of the intertubular dentin. Furthermore, studies on the SBS showed that the Er: YAG laser created a laser-modified layer that adversely affected the adhesion to dentin. In their study, Korkmaz *et al*.[18] demonstrated that the use of a Er: YAG laser for cavity preparation may interfere with the marginal sealing, as lased cavities showed a higher degree of leakage than those of conventionally bur-prepared teeth at the occlusal margin. The findings of Ozel *et al*.[44] suggest that the use of an Er: YAG laser for cavity preparation may decisively interfere with the marginal sealing, as lased cavities showed a higher degree of leakage than those of conventionally bur-prepared teeth at both the enamel and the cementum margins. Laser treatment did not have an additional effect on the bond strengths of the tested groups in the present study. The discrepancies between our results and those of previous studies[14,15,17,18,21,24,37] may be attributed to different testing methods and conditions, the varying nature of dentin as a substrate, the composite adhesive used or differences between the lasers and their energy parameters.

Several studies have assessed the ability of different settings of erbium lasers to improve marginal seal and bond strength.[6-8] Jaberi Ansari *et al*.[8] used different power settings of the Er, Cr:YSGG laser and compared the micro-SBS of composite restorations to tooth surfaces with restorations prepared by the conventional method. They reported a wide range of standard deviations in the laser groups, making it difficult to draw conclusions by comparing the results. In their study, Başaran *et al*.[9] showed that laser irradiation with lower power outputs demonstrated lower SBS while higher outputs showed higher SBS. Navarro *et al*.[20] showed that the Er: YAG laser irradiation parameters and pulse widths used for cavity preparation had no influence on the microleakage of composite resin restorations and scanning electron microscopy analysis of the morphology of cavities revealed a more conservative pattern resulting from the laser than from the conventionally preparation method. Uşümez *et al*.[22] compared the acid-etch technique with laser enamel etching at two different power settings (1 W, 2 W-20 Hz). The results indicate that etching of enamel surface with an Er, Cr:YSGG laser yielded statistically similar lower and less predictable bond strengths than etching with acid. Başaran *et al*.[9] discussed these contradictory findings and the possible effects of differences in the types of lasers used, the duration of exposure, the energy applied to the surface and the experimental design.

In the present study, silorane and micro-hybrid composite were compared with respect to the microleakage and bond strength in cavities prepared with a laser and a conventional bur. It was found relatively lower microleakage in the silorane groups compared with the micro-hybrid composites. The microleakage may be partly compensated for by the low shrinkage stress due to the silorane-based composite. The two-step self-etch silorane adhesive bonding material has less technical sensitivity than the total-etch system. Although the dental laser is popular in the dental literature, the specific advantages of its use for increasing bond strength or eliminating

microleakage remain unclear and *in vivo* studies are required.

CONCLUSION

Within the limitations of this *in vitro* study, it was concluded that composite restorations prepared with a diamond bur resulted similar bond strength and microleakage compared with laser at different power levels. In addition, Silorane (with two-step self-etch silorane adhesive) exhibited similar microleakage and SBS values compared with Filtek Z250 (with the total-etch system).

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